Carbon Monoxide Monitoring in

West Yellowstone, Montana 1998-2001

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May 2002

This report was prepared at the request of the Office of the Governor of the State of Montana as part of Montana's participation as a cooperative agency in the process of completing the Supplemental Environmental Impact Statement on Winter Use Plans for Yellowstone and Grand Teton National Parks and the John D. Rockefeller Jr. Memorial Parkway. Three of six entrances to Yellowstone National Park are within the State of Montana, and over 65 percent of all visitors to Yellowstone enter and exit Montana entrances.

Carbon Monoxide Ambient Monitoring in West Yellowstone, Montana

I. Introduction

The Monitoring and Data Management Bureau (MDMB) of the Montana Department of Environmental Quality (MDEQ) installed a Carbon Monoxide (CO) monitor next to the entrance of Yellowstone National Park in West Yellowstone during October 1998. The monitor is directly opposite of the entrance kiosk and is adjacent to the exit lane. The monitor measures CO levels continuously and reports hourly averages in Parts Per Million (PPM). MDEQ generally only operates CO monitors during the winter months (October through March) at other sites across the state, but this site has been in operation for 12 months a year since its installation. This report summarizes the results of the monitoring to date and presents an analysis of the mechanisms that the monitoring data reflects.

II. CO Monitoring Results in West Yellowstone Compared to Ambient Standards

CO is a product of incomplete combustion and is a criteria pollutant for which both national and state ambient air quality standards have been promulgated to protect the public health and welfare. The national and state standards are listed in Table 1.

Table 1
Carbon Monoxide Ambient Air Quality Standards

Averaging Period	National	Montana
1 hour	35 PPM*	23 PPM*
8 hour	9 PPM*	9 PPM*

*Not to be exceeded more than once per year

Monitoring results for the period from October 1998 through December 2001 are presented in Table 2 below.

Table 2
West Yellowstone Ambient CO Monitoring Results

PPM CO	1998*	1999	2000	2001
High 1-hour	11.1	18.2	17.9	16.0
2nd High 1-hour	8.0	13.5	17.4	13.7
High 8-hour	4.3	8.9	6.0	5.4
2nd High 8-hour	3.6	5.4	5.3	5.3

*October-December only.

During the 1998 through 2001 monitoring period the highest hourly value of CO recorded at the West Yellowstone site was 18.2 PPM. The highest 8-hour value was 8.9 PPM. These values both occurred during the Saturday of President's Day Weekend, February 13, 1999.

The next highest hourly value recorded was 17.9 PPM on December 28, 2000 and the next highest 8-hour value was 6 PPM on December 29, 2000. Spring, summer and fall CO levels are almost always less than 2 PPM. Other than one hour in August of 2000, all of the CO values measured at this site that exceed 3 PPM were measured during the winter months and are associated with snowmobile traffic. Violations of the Montana and National Ambient Air Quality Standards for CO have not been measured at the West Yellowstone site.

There seems to be a slight trend over the last four years towards lower CO impacts at the West Yellowstone site. A number of changes since that period are most likely responsible for this result. After the 1998-1999 season, ethanol blend fuel and low emissions lube oils were voluntarily introduced and used by West Yellowstone rental fleets and Park Service fleets. This change in the fuels and oils has reduced CO emissions somewhat. A new ticketing procedure was put in place after the 1998-1999 season that reduced the morning queues at the Park entry station across from the CO monitor. The advanced purchase of park passes and use of an "express lane" was used more than 70 percent of the time, especially during periods of high visitation. This has undoubtedly reduced CO emissions near the park entrance kiosks by shifting the emissions into West Yellowstone. It is no longer certain that the entrance site is representative of the expected highest CO levels in the West Yellowstone area. MDMB is considering relocating the monitor to a new site close to where most of the park passes are now being sold in the main West Yellowstone commercial area.

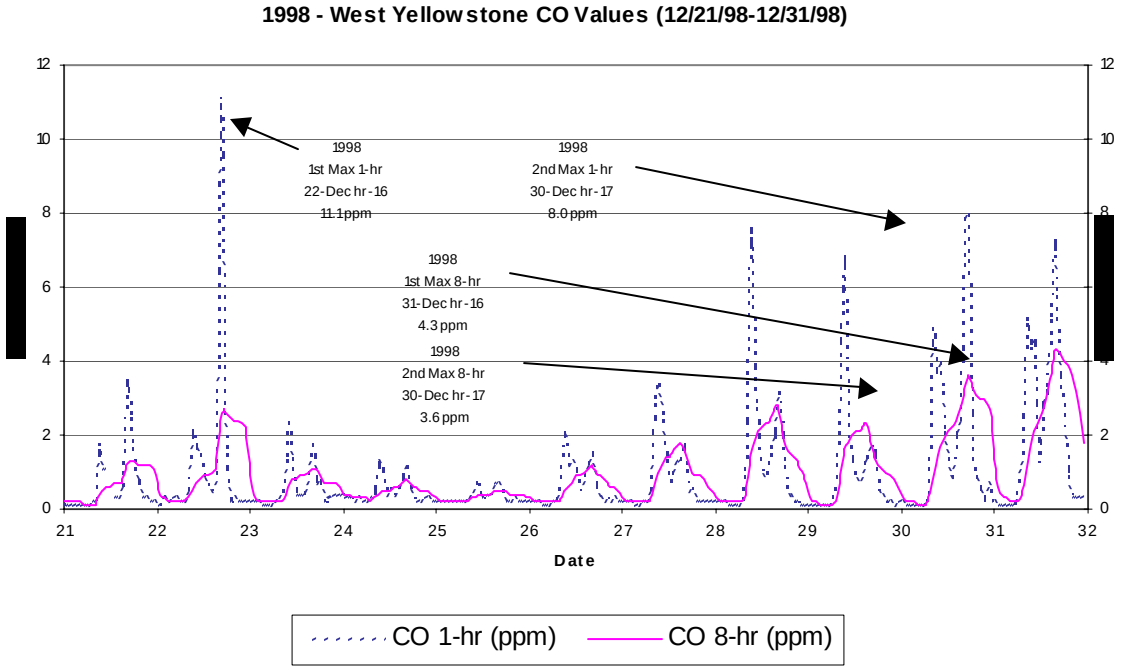
III. Mechanisms that are Responsible for Measured CO in West Yellowstone

Ambient CO levels at the West Yellowstone site are a function of two factors, CO emissions and meteorology. Changes in CO emission rates produces a linear response in measured CO levels. That is, a 50% increase in CO emissions would produce a 50% increase in measured CO levels if meteorological conditions remained constant.

Meteorological changes can easily change measured CO levels by several orders of magnitude and are the driving factor in producing elevated CO ambient levels in Montana. This is common phenomenon in Montana and other western states, where mountain valleys and persistent inversions can produce areas where even moderate levels of emissions can produce violations of the ambient air quality standards. CO is a quite stable gas and will persist for several hours under stagnant conditions. This allows a cumulative effect to occur where CO emissions from previous hours continue to impact the monitor and have the effect of raising the background values to the point where emissions that would not ordinarily produce a problem can elevate monitored values to very high levels.

Figure 1 is a good example of the way emission characteristics and meteorology can affect monitoring results. Figure 1 presents both hourly and running 8-hour average values measured at the West Yellowstone CO monitor for the period of December 21 through December 31, 1999. This was a period of heavy snowmobile usage, particularly during the period from Christmas to New Years Day. Daily snowmobile counts during periods of high usage reach about 3,500 sleds/day (1,750 in and 1,750 out).

Figure 1. Hourly and 8 Hour Running Average CO Monitoring Results for 10 days in December 1998.



CO levels start out near or at zero PPM each day, then spike up twice, in the morning and the afternoon. The morning peak reflects the CO impacts from sleds lining up at the entrance to pass into Yellowstone National Park. The afternoon peak is the result of another heavy traffic period as sleds exit the park late in the day. This same pattern is found at other CO monitoring sites in Montana and represents the linear nature of the connection between traffic levels and CO impacts.

The morning peak is usually substantially higher than the afternoon peak even though the total numbers of sleds passing by the monitor is the same. There are a number of reasons for this. In the morning, the sleds are lining up and there are periods of time where sleds are standing idle with the engines warming up. Average speeds through this morning period are also low as the sleds pass through the entrance lanes slowly and often stop. The result of these factors is that each sled emits more total exhaust gasses in the area of the monitor than they would if they passed straight through without delays. During the afternoon the sleds exit without stopping and the average speeds are much higher. This lowers the amount of exhaust emitted near the monitor.

There is also a strong meteorological component to this pattern. Strong inversions are present almost every morning during the winter months. The resultant low mixing heights and wind speeds trap the exhaust emissions near the ground and higher CO impacts are the result. As a general rule, inversions lift at least slightly during the afternoon as the day heats up. Wind speeds also generally increase slightly during the afternoon as well. These factors combine to lower the afternoon CO peak on most days as compared to the morning peak.

A close examination of the results for December 29th, 30th, and 31st reveals the consequence of change in this normal meteorological regime. The results for the 29th follow the pattern discussed above. CO levels peak in the morning and the afternoon levels are noticeably smaller. On the 30th this pattern is reversed. In this case, the afternoon peak is much higher than the morning peak and the highest 8-hour value for the day is almost doubled. During the afternoon of the 30th the inversion did not lift and the wind stayed calm. This allowed a buildup of CO to occur and during the afternoon the CO levels at the monitor reflected both the immediate impact of the afternoon traffic peak and a residual impact from CO emitted earlier in the day. The stagnant period persisted into December 31st and even though CO levels dropped to near zero overnight, the 8-hour CO value measured that day was the highest measured during the 1998 portion of the 1998-1999 winter.

This pattern of persistent stagnation is responsible for all of the highest monitored CO levels at this site during the past four years. All of the highest 1-hour and 8-hour values were measured on days when the inversions did not lift and the winds did not blow during the afternoon.

IV. West Yellowstone CO Compared to other Sites in Montana

During the period MDEQ has been monitoring CO at West Yellowstone, the maximum hourly values measured have been substantially higher than those monitored anywhere else in the state. Maximum 8-hour values measured were higher during two of the most recent three years of complete data. Table 3 shows the CO values measured in Montana during the 1999-2001 time period.

Table 3. Comparison of CO Levels (PPM) in Six Montana Cities

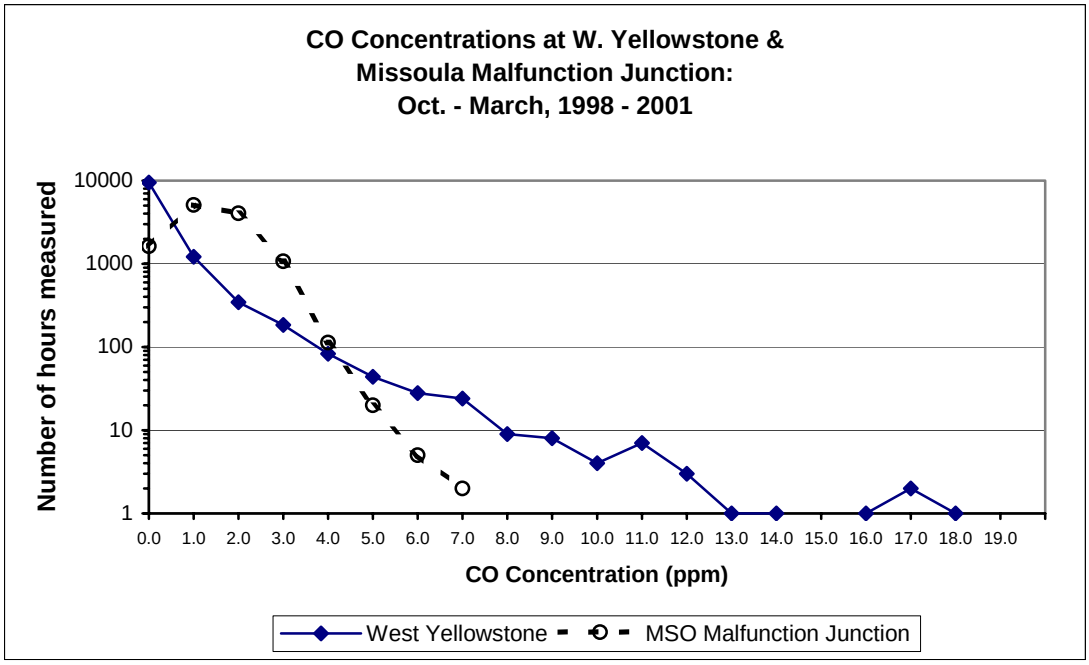
City	1999 Max 1-hour	2000 Max 1-hour	2001 Max 1-hour	1999 Max 8-hour	2000 Max 8-hour	2001 Max 8-hour
Billings	8.5	10.6	9.0	6.0	5.1	5.6
Butte	7.7	6.3	10.8	4.6	5.0	4.3
Great Falls	7.8	6.7	7.4	3.6	4.6	4.6
Kalispell	9.1	8.0	6.0	5.3	4.2	3.8
Missoula	6.0	5.4	7.7	4.9	3.9	5.5
West Yellowstone	18.2	17.9	16.0	8.9	6.0	5.4

MDMB has prepared an analysis comparing the CO values measured in Missoula to those in West Yellowstone. MDEQ has been monitoring CO at the Missoula Malfunction Junction site for many years. Missoula is a CO non-attainment area and CO emissions in Missoula are controlled with a State Implementation Plan (SIP) to assure compliance with the ambient air quality standard. This plan relies on a substantial re-construction of the intersection to improve the traffic flow, a requirement for the use of oxygenated fuels during the winter months and a marked improvement in vehicle emission rates due to fleet turnover and new federal limits for vehicle

emissions. The Malfunction Junction site is at the intersection of three major arterial streets in Missoula. Total daily traffic through the intersection is about 55,000 vehicles a day; traffic counts for the busiest hours are in the 6,000-7,000 range.

Figure 2 presents a frequency distribution analysis of hourly CO values measured at West Yellowstone and Missoula during the winter months, 1998 through 2001.

Figure 2. Comparison of CO Values at Missoula and West Yellowstone



Missoula has many more CO hourly values recorded in the 1-PPM to 3-PPM range than West Yellowstone. Both sites have about the same number of 4-PPM CO measurements, but West Yellowstone had both more and higher CO values than Missoula in the 5-PPM and greater range.

Dispersion characteristics are expected to be mostly similar in Missoula and West Yellowstone; the differences are due to several other factors. The site in Missoula sits in the middle of an area of emissions with roads in all directions. No matter what direction the

wind is blowing, the monitor is downwind of some emission sources. The West Yellowstone monitor only has emissions to the south. When the wind blows from the north, CO levels at the monitor go to zero. If the West Yellowstone monitor was located in a more central location, there would likely be fewer occasions when the monitor measures CO values less than 0.5 PPM (values of 0.4 PPM and below are treated as zero for this analysis).

Traffic activity in Missoula is spread through more of the day than is the case in West Yellowstone. Virtually all of the traffic past the monitor in West Yellowstone occurs during two hours in the morning and two hours in the afternoon. The busiest four hours in Missoula would only represent about 40% of the total daily traffic. As a result, West Yellowstone has many more opportunities each day to measure very low CO values in the area near the entrance gate.

The day-to-day distribution of the emissions at the two sites is also substantially different. Busy traffic days at the West Yellowstone site (Weekends and Holidays) have up to ten times the traffic volume of slow days. Daily fluctuations in Missoula traffic operate over a much smaller range. There will likely continue to be a greater number of very low CO measurements in West Yellowstone than in Missoula, but moving the monitor into the central part of West Yellowstone where the traffic pattern is more evenly distributed and the wind direction is not as critical should even out some of the differences in the distribution of hours measuring 3-PPM and less.

The incidence of higher CO values in West Yellowstone is due to higher total CO emissions produced by vehicles passing that monitor. CO emission rates for snowmobiles are substantially higher than the rates for cars and trucks.

V. Emission Rates versus Monitor Results

If the dispersion characteristic of the two sites are substantially similar, a comparison of the monitoring results leads to the conclusion that the total emissions from the 500-700 snowmobiles passing by the West Yellowstone monitor during the busiest hours are about three times higher than the total from the 6,000-7,000 vehicles passing by the Missoula monitor during its busiest hours. That is,

impacts from about one tenth of the snowmobile traffic produces results 3 times higher at the monitor. It would appear from the monitoring results that snowmobile emissions are about 30 times higher than a normal car and truck mix.

Estimated average emissions for the Missoula fleet are in the range of 15-20 grams/vehicle kilometer traveled (g/vkt). Estimated emission rates for snowmobiles are in the range of 400 to 600 g/vkt. This ratio of emission rates compares well with the ratio of the monitoring data.

VI. Summary and Conclusions

CO emissions from snowmobiles in West Yellowstone can result in high measured CO ambient levels that approach and could exceed the national and state air quality standards, even though pollution at the kiosk has been reduced by use of an express lanes and cleaner fuels. The monitor at the West Entrance in West Yellowstone is probably no longer representative of the expected worst-case impact area and needs to be moved into the center of town to better characterize the exposure of the population to CO from all of the sources. Continued growth of conventional 2-stroke snowmobile activity levels in West Yellowstone will make the situation worse if the snowmobile emission rates are not substantially improved.